INTERNATIONAL STANDARD

IEC 60068-2-6

Sixth edition
1995-03

BASIC SAFETY PUBLICATION

Environmental testing –

Part 2: Tests – Test Fc: Vibration (sinusoidal)

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

Reference number
IEC 60068-2-6:1995(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE X

For price, see current catalogue

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 68-2-6 has been prepared by sub-committee 50A: Vibration, impact and other dynamic tests, of IEC technical committee 50: Environmental testing.

This sixth edition cancels and replaces the fifth edition published in 1982, amendments 1 (1983) and 2 (1985), and constitutes a technical revision.

It has the status of a basic safety publication in accordance with IEC Guide 104.

The text of this standard is based on the following documents:

DIS	Report on voting
50A(CO)232	50A/294/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

IEC 68 consists of the following parts, under the general title: Environmental testing

Part 1: General and guidance
Part 2: Tests
Part 3: Background information
Part 4: Information for specification writers – Test summaries
Part 5: Guide to drafting of test methods

Annexes A, B and C of this standard are for information only.

INTRODUCTION

This part of IEC 68 gives a method of test applicable to components, equipment and other articles which, during transportation or in service, may be subjected to conditions involving vibration of a harmonic pattern, generated primarily by rotating, pulsating or oscillating forces, such as occur in ships, aircraft, land vehicles, rotorcraft and space applications or are caused by machinery and seismic phenomena.

This standard consists basically of subjecting a specimen to sinusoidal vibration over a given frequency range or at discrete frequencies, for a given period of time. A vibration response investigation may be specified which aims at determining critical frequencies of the specimen.

The relevant specification shall indicate whether the specimen shall function during vibration or whether it suffices that it still works after having been submitted to vibration.

It is emphasized that vibration testing always demands a certain degree of engineering judgement, and both the supplier and purchaser should be fully aware of this fact. However, sinusoidal testing is deterministic and, therefore, relatively simple to perform. Thus it is readily applicable to both diagnostic and service life testing.

The main part of this standard deals primarily with the methods of controlling the test at specified points using either analogue or digital techniques, and gives, in detail, the testing procedure. The requirements for the vibration motion, choice of severities including frequency ranges, amplitudes and endurance times are also specified; these severities representing a rationalized series of parameters. The relevant specification writer is expected to choose the testing procedure and values appropriate to the specimen and its use.

Certain terms have been defined to facilitate a proper understanding of the text. These definitions are given in clause 3.

Annex A gives general guidance for the test and annexes B and C provide guidance on the selection of severities for components and equipment.

ENVIRONMENTAL TESTING –

Part 2: Tests –
Test Fc: Vibration (sinusoidal)

1 Scope

This part of IEC 68 gives a method of test which provides a standard procedure to determine the ability of components, equipment and other articles, hereinafter referred to as specimens, to withstand specified severities of sinusoidal vibration.

The purpose of this test is to determine any mechanical weakness and/or degradation in the specified performance of specimens and to use this information, in conjunction with the relevant specification, to decide the acceptability of the specimens. In some cases, the test method may also be used to demonstrate the mechanical robustness of specimens and/or to study their dynamic behaviour. Categorization of components can also be made on the basis of a selection from within the severities quoted in the test.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 68. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 68 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(721): 1991, *International Electrotechnical Vocabulary (IEV) – Chapter 721: Telegraphy facsimile and data communication*

IEC 68-1: 1988, *Environmental testing – Part 1: General and guidance*
Amendment 1 (1992)

IEC 68-2-34: 1973, *Environmental testing – Part 2: Tests – Test Fd: Random vibration wide band – General requirements**
Amendment 1 (1983)

IEC 68-2-35: 1973, *Environmental testing – Part 2: Tests – Test Fda: Random vibration wide band – Reproducibility High**
Amendment 1 (1983)

IEC 68-2-36: 1973, *Environmental testing – Part 2: Tests – Test Fdb: Random vibration wide band – Reproducibility Medium**
Amendment 1 (1983)

* Tests Fd, Fda, Fdb and Fdc are to be withdrawn in 1998.

IEC 68-2-37: 1973, *Environmental testing – Part 2: Tests – Test Fdc: Random vibration wide band – Reproducibility Low**
Amendment 1 (1983)

IEC 68-2-47: 1982, *Environmental testing – Part 2: Tests – Mounting of components, equipment and other articles for dynamic tests including shock (Ea), bump (Eb), vibration (Fc and Fd) and steady-state acceleration (Ga) and guidance*

IEC 68-2-64: 1993, *Environmental testing – Part 2: Tests – Test Fh: Vibration broad-band random (digital control) and guidance*

IEC 721-1: 1990, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*
Amendment 1 (1992)

ISO 2041: 1990, *Vibration and shock – Vocabulary*

3 Definitions

Definitions in alphabetical order:

Actual motion	3.7
Basic motion	3.6
Centred resonance frequency	3.10
Check point	3.2.1
Critical frequencies	3.9
Damping	3.8
Fictitious reference point	3.2.2.1
Fixing point	3.1
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Measuring points	3.2
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Reference point	3.2.2
Restricted frequency sweeping	3.11
Signal tolerance	3.5
Single point control	3.3.1
Sweep cycle	3.4

The terms used are generally as defined in ISO 2041 and in IEC 68-1. However, sweep cycle (3.4) and signal tolerance (3.5) have specific meanings in this standard.

The other terms described below are not identical to, or not defined in, ISO 2041 or in IEC 68-1.

3.1 **fixing point:** Part of the specimen in contact with the fixture or vibration table at a point where the specimen is normally fastened in service. If a part of the real mounting structure is used as the fixture, the fixing points shall be taken as those of the mounting structure and not of the specimen.

3.2 **measuring points:** The test is carried out using data gathered at certain specific points. These are of two main types, the definitions of which are given below.

NOTE – Measurements may be made at points within the specimen in order to assess its behaviour, but these are not considered as measuring points in the sense of this standard. For further details, see A.2.1.

3.2.1 **check point:** Point located on the fixture, on the vibration table or on the specimen as close as possible to one of its fixing points, and in any case rigidly connected to it.

NOTES

1 A number of check points are used as a means of ensuring that the test requirements are satisfied.

2 If four or fewer fixing points exist, each is used as a check point. If more than four fixing points exist, four representative fixing points will be defined in the relevant specification to be used as check points.

3 In special cases, for example for large or complex specimens, the check points will be prescribed in the relevant specification if not close to the fixing points.

4 Where a large number of small specimens are mounted on one fixture, or in the case of a small specimen where there are several fixing points, a single check point (i.e. the reference point) may be selected for the derivation of the control signal. This signal is then related to the fixture rather than to the fixing points of the specimen(s). This is only valid when the lowest resonance frequency of the loaded fixture is well above the upper frequency of the test.

3.2.2 **reference point:** Point chosen from the check points whose signal is used to control the test, so that the requirements of this standard are satisfied.

3.2.2.1 **fictitious reference point:** A fictitious point derived from multiple check points either manually or automatically, the result of which is used to control the test, so that the requirements of this standard are satisfied.

3.3 *Control points*

3.3.1 **single point control:** This is achieved by using the signal from the transducer at the reference point in order to maintain this point at the specified level (see 4.1.4.1).

3.3.2 **multipoint control:** This is achieved by using the signals from each of the transducers at the check points. The signals are either continuously averaged arithmetically or processed by using comparison techniques, depending upon the relevant specification (see 4.1.4.1).

3.4 **sweep cycle:** A traverse of the specified frequency range once in each direction, for example 10 Hz to 150 Hz to 10 Hz.

NOTE – Manufacturer's handbooks for digital sine control systems often refer to a sweep cycle as f_1 to f_2, not f_1 to f_2 to f_1.

3.5 **signal tolerance:** Signal tolerance $T = \left(\frac{NF}{F} - 1\right) \times 100$ (per cent).

where

NF is the r.m.s value of the unfiltered signal;

F is the r.m.s value of the filtered signal.

NOTE – This parameter applies to whichever signal, i.e. acceleration, velocity or displacement, is being used to control the test. (see A.2.2)

3.6 **basic motion:** Motion at the driving frequency of vibration at the reference point (see also 4.1.1).

3.7 **actual motion:** Motion represented by the wideband signal returned from the reference point transducer.

3.8 **damping:** The generic term ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends on many parameters, such as the structural system, mode of vibration, strain, applied forces, velocity, materials, joint slippage, etc.

3.9 **critical frequencies:** Frequencies at which:

- malfunctioning and/or deterioration of performance of the specimen are exhibited which are dependent on vibration, and/or
- mechanical resonances and/or other response effects occur, for example, chatter.

3.10 **centred resonance frequency:** Frequency automatically centred on the actual resonance frequency derived from the vibration response investigation.

3.11 **restricted frequency sweeping:** Sweeping over a restricted frequency range between 0,8 and 1,2 times the critical frequency.

3.12 g_n**:** Standard acceleration due to the earth's gravity, which itself varies with altitude and geographical latitude.

NOTE – For the purpose of this standard, the value of g_n is rounded up to the nearest whole number, that is 10 m/s^2.

4 Requirements for testing

4.1 *Required characteristics*

The required characteristics apply to the complete vibration system, which includes the power amplifier, vibrator, test fixture, specimen and control system when loaded for testing.

4.1.1 *Basic motion*

The basic motion shall be a sinusoidal function of time and such that the fixing points of the specimen move substantially in phase and in straight parallel lines, subject to the limitations of 4.1.2 and 4.1.3.

4.1.2 *Spurious motion*

4.1.2.1 *Transverse motion*

The maximum vibration amplitude at the check points in any axis perpendicular to the specified axis shall not exceed 50 % of the specified amplitude up to 500 Hz or 100 % for frequencies in excess of 500 Hz. The measurements need only cover the specified frequency range. In special cases, e.g. small specimens, the amplitude of the permissible transverse motion may be limited to 25 %, if required by the relevant specification.

In some cases, for example for large size or high mass specimens or at some frequencies, it may be difficult to achieve the figures quoted above. In such cases the relevant specification shall state which of the following requirements apply:

a) any transverse motion in excess of that stated above shall be noted and stated in the test report; or

b) transverse motion which is known to offer no hazard to the specimen need not be monitored.

4.1.2.2 *Rotational motion*

In the case of large size or high mass specimens, the occurrence of spurious rotational motion of the vibration table may be important. If so, the relevant specification shall prescribe a tolerable level. The achieved level shall be stated in the test report (see also A.2.4).

4.1.3 *Signal tolerance*

Unless otherwise stated in the relevant specification, acceleration signal tolerance measurements shall be performed. They shall be carried out at the reference point and shall cover the frequencies up to 5 000 Hz or five times the driving frequency whichever is the lesser. However, this maximum analysing frequency may be extended to the upper test frequency for the sweep, or beyond, if specified in the relevant specification. Unless otherwise stated in the relevant specification, the signal tolerance shall not exceed 5 % (see 3.5).

If stated in the relevant specification, the acceleration amplitude of the control signal at the fundamental driving frequency shall be restored to the specified value by use of a tracking filter (see A.4.4).

In the case of large or complex specimens, where the specified signal tolerance values cannot be satisfied at some parts of the frequency range and it is impracticable to use a tracking filter, the acceleration amplitude need not be restored, but the signal tolerance shall be stated in the test report (see A.2.2).

NOTE – If a tracking filter is not used and the signal tolerance is in excess of 5 %, the reproducibility may be significantly affected by the choice of either a digital or analogue control system (see A.4.5).

The relevant specification may require that the signal tolerance, together with the frequency range affected, is stated in the test report whether or not a tracking filter has been used (see A.2.2).

4.1.4 *Vibration amplitude tolerances*

The basic motion amplitude in the required axis at the check and reference points shall be equal to the specified value, within the following tolerances. These tolerances include instrumentation errors. The relevant specification may require that the confidence level used in the assessment of measurement uncertainty is stated in the test report.

At low frequencies or with large size or high mass specimens it may be difficult to achieve the required tolerances. In these cases it is expected that a wider tolerance or the use of an alternative method of assessment shall be prescribed in the relevant specification and stated in the test report.

4.1.4.1 *Reference point*

Tolerance on the control signal at the reference point: ±15 % (see A.2.3).

The relevant specification shall state whether single point or multipoint control shall be used. If multipoint control is prescribed, the relevant specification shall state whether the average value of the signal at the check points or the value of the signal at a selected point (for example, that with the largest amplitude) shall be controlled to the specified level (see A.2.3).

NOTE – If it is not possible to achieve single point control, then multipoint control may be used by controlling the average or extreme value of the signals at the check points. In either of these cases of multipoint control, the point is a fictitious reference point. The method used shall be stated in the test report.

4.1.4.2 *Check points*

At each check point:

±25 % up to 500 Hz;

±50 % above 500 Hz.

(See A.2.3.)

4.1.5 *Frequency tolerances*

The following frequency tolerances apply.

4.1.5.1 *Endurance by sweeping*

±0,05 Hz up to 0,25 Hz;

±20 % from 0,25 Hz to 5 Hz;

±1 Hz from 5 Hz to 50 Hz;

±2 % above 50 Hz.

4.1.5.2 *Endurance at fixed frequency*

a) Fixed frequency:

±2 %.

b) Almost fixed frequency:

±0,05 Hz up to 0,25 Hz;

±20 % from 0,25 Hz to 5 Hz;

±1 Hz from 5 Hz to 50 Hz;

±2 % above 50 Hz.

4.1.5.3 *Measurement of critical frequency*

When the critical frequencies (see 8.1) before and after endurance are to be compared, i.e. during vibration response investigations, the following tolerances shall apply:

±0,05 Hz up to 0,5 Hz;

±10 % from 0,5 Hz to 5 Hz;

±0,5 Hz from 5 Hz to 100 Hz;

±0,5 % above 100 Hz.

4.1.6 *Sweep*

The sweeping shall be continuous and the frequency shall change exponentially with time (see A.4.3). The sweep rate shall be one octave per minute with a tolerance of ±10 %. This may be varied for a vibration response investigation (see 8.1).

NOTE – With a digital control system it is not strictly correct to refer to the sweeping being "continuous", but the difference is of no practical significance.

4.2 *Mounting*

Unless otherwise stated in the relevant specification, the specimens shall be mounted on the test apparatus in accordance with the requirements in IEC 68-2-47. For specimens normally mounted on vibration isolators, see in addition 8.2.2 NOTE, A.3.1, A.3.2 and A.5.

5 Severities

A vibration severity is defined by the combination of the three parameters: frequency range, vibration amplitude and duration of endurance (in sweep cycles or time).

For each parameter, the relevant specification shall choose the appropriate requirements from those listed below or derived from other known sources of relevant data (for example IEC 721). If the known environment is substantially different, the requirements shall be related to it by the relevant specification.

To permit some flexibility in situations where the real environment is known, it may be appropriate to specify a shaped acceleration versus frequency curve and in these cases the relevant specification shall prescribe the shape as a function of frequency. The different levels and their corresponding frequency ranges, that is the break points, shall be selected, wherever possible, from the values given in this standard.

Examples of severities for components are given in annex B and for equipment in annex C (see also A.4.1 and A.4.2).

5.1 *Frequency range*

The frequency range shall be stated in the relevant specification by selecting a lower frequency from table 1 and an upper frequency from table 2. The recommended ranges are shown in table 3.

Examples of ranges for particular applications are given in tables B.1, C.1 and C.2.

Table 1 – Lower frequency

f_1 Hz
0,1
1
5
10
55
100

Table 2 – Upper frequency

f_2 Hz
10
20
35
55
100
150
300
500
2 000
5 000

Table 3 – Recommended frequency ranges

From f_1 to f_2 Hz
1 to 35
1 to 100
10 to 55
10 to 150
10 to 500
10 to 2 000
10 to 5 000
55 to 500
55 to 2 000
55 to 5 000
100 to 2 000

5.2 *Vibration amplitude*

The vibration amplitude (displacement or acceleration or both) shall be stated in the relevant specification.

Below a certain frequency known as the cross-over frequency, all amplitudes are specified as constant displacement, whilst above this frequency, amplitudes are given as constant acceleration. The recommended values are stated in tables 4 and 5 for the two different cross-over frequencies.

Each value of displacement amplitude is associated with a corresponding value of acceleration amplitude (shown on the same line in tables 4 and 5) so that the amplitude of vibration is the same at the cross-over frequency (see A.4.1).

Where it is not technically appropriate to adopt the cross-over frequencies stated in this subclause, the relevant specification may couple displacement and acceleration amplitudes giving a different value of cross-over frequency. In some circumstances more than one cross-over frequency may also be specified.

NOTE – Nomograms relating vibration amplitude to frequency are given in figures 1, 2 and 3 but, before their use in the low-frequency region, consideration should be given to the guidance in A.4.1.

Up to an upper frequency of 10 Hz, it is normally appropriate to specify a displacement amplitude over the whole frequency range. Therefore, in table 6 and figure 3 only displacement amplitudes are specified.

Table 4 – Recommended vibration amplitudes with lower cross-over frequency (8 Hz to 10 Hz)

Displacement amplitude below the cross-over frequency		Acceleration amplitude above the cross-over frequency	
mm	(in)	m/s^2	(g_n)
0,35	(0,014)	1	(0,1)
0,75	(0,03)	2	(0,2)
1,5	(0,06)	5	(0,5)
3,5	(0,14)	10	(1,0)
7,5	(0,30)	20	(2,0)
10	(0,40)	30	(3,0)
15	(0,60)	50	(5,0)

NOTES

1 All figures quoted are amplitudes (peak values).

2 The inch values which are given for information are derived from the original millimetric values and are approximate. Similarly, the g_n values are given for information.

3 The displacement amplitude of 15 mm is primarily intended for hydraulic vibration generators.

Table 5 – Recommended vibration amplitudes with higher cross-over frequency (58 Hz to 62 Hz)

Displacement amplitude below the cross-over frequency		Acceleration amplitude above the cross-over frequency	
mm	(in)	m/s^2	(g_n)
0,035	(0,0014)	5	(0,5)
0,075	(0,003)	10	(1,0)
0,15	(0,006)	20	(2,0)
0,35	(0,014)	50	(5,0)
0,75	(0,03)	100	(10)
1,0	(0,04)	150	(15)
1,5	(0,06)	200	(20)
2,0	(0,08)	300	(30)
3,5	(0,14)	500	(50)

NOTES

1 All figures quoted are amplitudes (peak values).

2 The inch values which are given for information are derived from the original millimetric values and are approximate. Similarly, the g_n values are given for information.

Table 6 – Recommended vibration displacement amplitudes applicable only for frequency ranges with an upper frequency of 10 Hz

Displacement amplitude	
mm	(in)
10	(0,40)
35	(1,4)
75	(3,0)
100	(4,0)

NOTES

1 All figures quoted are amplitudes (peak values).

2 The inch values which are given for information are derived from the original millimetric values and are approximate.

3 The displacement amplitudes of greater than 10 mm are primarily intended for hydraulic vibration generators.

5.3 *Duration of endurance*

The relevant specification shall select the duration(s) from the recommended values given below. If the specified duration leads to an endurance time of 10 h or more per axis or frequency, this time may be split into separate testing periods provided that stresses in the specimen are not thereby reduced (see A.1 and A.6.2).

5.3.1 *Endurance by sweeping*

The duration of the endurance in each axis shall be given as a number of sweep cycles (see 3.4) chosen by the relevant specification from the list given below:

1, 2, 5, 10, 20, 50, 100.

When a higher number of sweep cycles is required, the same series should be applied (see A.4.3).

5.3.2 *Endurance at fixed frequencies*

5.3.2.1 *Endurance at critical frequencies*

The duration of the endurance in each appropriate axis at each frequency found during the vibration response investigation (see 8.1) shall be chosen by the relevant specification from the values given below with a tolerance of $^{+5}_{0}$% (see A.1 and A.6.2):

10 min; 30 min; 90 min; 10 h.

For almost fixed frequencies, see A.1.

5.3.2.2 *Endurance at predetermined frequencies*

The duration stated in the relevant specification shall take into account the total time the specimen is expected to be submitted to such vibration during its operational life. An upper limit of 10^7 stress cycles shall apply for each stated combination of frequency and axis (see A.1 and A.6.2).

6 Pre-conditioning

The relevant specification may call for pre-conditioning and shall then prescribe the conditions (see IEC 68-1).

7 Initial measurements

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification (see A.9).

8 Testing

Unless otherwise stated in the relevant specification, the specimen shall be vibrated in three mutually perpendicular axes, in turn, which should be so chosen that faults are most likely to be revealed.

8.1 *Vibration response investigation*

When called for in the relevant specification, the response of the specimen in the defined frequency range shall be investigated in order to study the behaviour of the specimen under vibration. Normally, the vibration response investigation shall be carried out over a sweep cycle under the same conditions as for the endurance (see 8.2), but the vibration amplitude may be diminished and the sweep rate decreased below the specified value if, thereby, more precise determination of the response characteristics can be obtained. Undue dwell time and overstressing of the specimen shall be avoided (see A.3.1).

The specimen shall be functioning during this vibration response investigation if required by the relevant specification. Where the mechanical vibration characteristics cannot be assessed because the specimen is functioning, an additional vibration response investigation with the specimen not functioning shall be carried out.

During the vibration response investigation, the specimen and the vibration response data shall be examined in order to determine critical frequencies. These frequencies, applied amplitudes and the behaviour of the specimen shall be stated in the test report (see clause A.1). The relevant specification shall state what action shall be taken.

When digital control is used, care shall be taken when determining the critical frequencies from the plot of the response curve, due to limitations as a result of the number of data points per sweep chosen, or the discrimination ability of the control system display screen (see A.3.1).

In certain circumstances, the relevant specification may require an additional vibration response investigation on completion of an endurance procedure so that the critical frequencies before and after can then be compared. The relevant specification shall state what action is to be taken if any change of frequency occurs. It is essential that both vibration response investigations are carried out in the same manner and at the same vibration amplitudes (see 4.1.5.3 and A.3.1).

8.2 *Endurance procedures*

The relevant specification shall prescribe which of the following endurance procedures shall be employed.

8.2.1 *Endurance by sweeping*

This endurance procedure is preferred.

The frequency shall be swept over the frequency range at the sweep rate, the amplitude and for the duration selected by the relevant specification (see 5.3.1). If necessary, the frequency range may be sub-divided, provided that the stresses in the specimen are not thereby reduced.

8.2.2 *Endurance at fixed frequencies*

Vibration shall be applied either at:

a) those frequencies derived from the vibration response investigation given in 8.1, using one of the following methods:

1) fixed frequency,

– centred resonance frequency.

The applied frequency shall always be maintained at the actual critical frequency.

2) almost fixed frequency,

– restricted frequency sweeping.

If the actual critical frequency is not clearly evident, for example if there is chatter, or where a number of individual specimens are being tested simultaneously, it may be convenient to sweep over a restricted frequency range between 0,8 and 1,2 times the critical frequency in order to be sure of exciting the effect fully. This may also apply where the resonance is non-linear (see A.1).

b) predetermined frequencies stated in the relevant specification.

The test shall be applied at the amplitude and for the duration stated in the relevant specification (see A.3.2).

NOTE – In the case of a specimen mounted on vibration isolators, the relevant specification will need to state whether or not the resonance frequencies of the specimen on its isolators should be chosen for this endurance (see A.5).

9 Intermediate measurements

When prescribed by the relevant specification, the specimen shall be functioning and its performance checked during the test for the specified proportion of the total time (see A.3.2 and A.8).

10 Recovery

It is sometimes necessary, when prescribed by the relevant specification, to provide a period of time after testing and before final measurements to allow the specimen to attain the same conditions, for example of temperature, as existed for the initial measurements. The relevant specification shall prescribe the precise conditions for recovery.

11 Final measurements

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based (see A.9).

12 Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given in so far as they are applicable, paying particular attention to the items marked with an asterisk (*) as this information is always required.

	Clause and/or subclause
a) Choice of check points	3.2.1
b) Choice of control points*	3.3.2
c) Transverse motion	4.1.2.1
d) Rotational motion	4.1.2.2
e) Signal tolerance	4.1.3
f) Vibration amplitude tolerance	4.1.4
g) Confidence level	4.1.4
h) Single or multipoint control*	4.1.4.1
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Annex A
(informative)

Guide to test Fc

A.1 Introduction

The test provides a method by which effects comparable with those likely to be experienced in practice can be reproduced in the test laboratory. The basic intention is not necessarily to reproduce the real environment.

The parameters given are standardized and suitable tolerances chosen in order to obtain similar results when a test is run at different locations by different people using either analogue or digital control techniques. The standardization of values also enables components to be grouped into categories corresponding to their ability to withstand certain vibration severities given in this standard.

In vibration testing, the usual approach in previous specifications has been to search for the resonances and then to undertake an endurance test in which a specimen is vibrated at resonance frequencies for a prescribed time. Unfortunately, it is difficult to differentiate, by means of a general definition, between resonances which are liable to cause failure in service and those unlikely to cause trouble, even when the specimen is vibrated for long periods.

In addition, such testing procedures are often unrealistic when applied to the majority of modern specimens. Direct observation is almost impossible in the assessment of vibration characteristics of any enclosed item, or of modern miniaturized assemblies. Vibration transducer techniques often cannot be applied without altering the mass-stiffness distribution of the assembly. In cases where transducers can be used, success depends entirely on the skill and experience of the test engineer in selecting appropriate points in the assembly for measurement.

The procedure preferred here, i.e. endurance by sweeping, minimizes these difficulties and avoids the necessity of defining significant or damaging resonances. The recommendation of this method has been influenced by the need to specify test methods which are as well defined as the present state of environmental testing will allow, and which reduce the dependence upon the skill of the test engineer to a minimum. The endurance by sweeping is given by the number of sweep cycles which are derived from related numbers of stress cycles.

The procedure may, however, in some cases lead to inconveniently long times if the endurance duration is intended to be long enough to ensure a fatigue life comparable to the required service time, or unlimited fatigue life under conditions of vibration comparable with those experienced in service. Therefore, other methods have been given, including endurance at fixed frequencies, which are either predetermined or found during the response investigation. It is expected that fixed frequency endurance is applicable if, during the vibration response investigation, the number of such frequencies in each axis is found to be small and not normally exceeding four. If the number exceeds four, endurance by sweeping may be more appropriate.

In the case of almost fixed frequencies the duration of endurance should be based on the values stated for critical frequencies. However, to the selected value, a proportion of that time should be added which is dependant upon the range of critical frequencies of the specimens (see 5.3.2.1).

It may be appropriate to carry out endurance testing both by sweeping and at fixed frequencies. It needs to be remembered that endurance at fixed frequencies still requires a certain amount of engineering judgement in application.

In addition, for any predetermined frequency, the endurance time needs to be given in the relevant specification.

The fixed frequency endurance is given as time in the case of critical frequencies. This time is often based on an anticipated number of stress cycles. Owing to the wide variety of materials it is obvious that no realistic single figure could be given for the number of stress cycles. Nevertheless, it is considered that 10^7 is a sufficiently practicable upper figure to be quoted for general vibration testing and need not be exceeded (see 5.3.2.1 and 5.3.2.2).

In some cases where there is a high level of background vibration which may be of a random or complex nature, sinusoidal testing may not be adequate. It is, therefore, left to the user to determine if sinusoidal testing alone is suitable for the particular application.

If it is known that the real environment is essentially random vibration, a random vibration test should be used for the endurance phase wherever economically possible. This is particularly applicable in the case of equipment. For some component-type specimens of simple construction a sinusoidal test is usually adequate. The random vibration tests are dealt with in IEC 68-2-34*, IEC 68-2-35*, IEC 68-2-36*, IEC 68-2-37* and for digital control in IEC 68-2-64.

A.2 Measurement and control

A.2.1 *Measuring points*

Two main types of measuring points are defined in clause 3. However, on occasions it may be necessary to measure local responses within a specimen in order to establish that the vibration at these points is not likely to cause damage. Under certain circumstances such as during the design stage, it may even be necessary to incorporate the signals from such measuring points into the control loop in order to avoid costly degradation of the specimen. It should be noted, however, that this technique is not recommended herein as it cannot be standardized (see 3.2).

A.2.2 *Errors caused by signal tolerance*

Where the signal tolerance is less than 5 % there is no practical difference between actual motion and basic motion.

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* These standards are to be withdrawn in 1998.

Where a small size or low mass specimen is used with a large vibration table there should generally not be a problem with signal tolerance. Indeed, where system signal tolerance measurements were taken when the vibration system was newly installed, the original measurements may be assumed to apply. However, laboratories need to be aware of potential problems with large specimens.

In cases where the signal tolerance is high, the measuring system will indicate a vibration level which is incorrect since it contains the required frequency and many unwanted frequencies. This will result in a lower amplitude at the required frequency than is specified. Up to the signal tolerance value specified in 4.1.3, this error can be tolerated; however, above this value it may be necessary to restore the level of the fundamental to its required amplitude. There are a number of ways of doing this, but it is recommended that a tracking filter be used. If the level of the fundamental is restored, the specimen will be subjected to the intended stress at the required frequency.

It may be that, under these conditions, the unwanted frequencies will also increase and as a result some additional stresses will be caused. If this gives rise to unrealistically high stresses, it may be more appropriate to waive the signal tolerance level requirement prescribed in the relevant specification (see 4.1.3).

For a digital system, additional information on the wide band unfiltered control signal can be obtained by passing the signal into a spectrum analyser. An analysis can then be performed over the specified frequency range and will show the fundamental, harmonics and other noise content, caused, for example, by chattering and impacting.

NOTE – The relationship between distortion D and signal tolerance T is given by:

$$\frac{D}{100} = \sqrt{\left(\frac{T}{100}\right)^2 + \frac{2 \times T}{100}}$$

where D and T are expressed as percentage values.

(When a signal tolerance $T = 5$ is inserted in the above equation a distortion $D = 32$ will result.)

A.2.3 *Derivation of control signal*

A number of methods are available for derivation of the control signal.

If an averaged multipoint control signal is specified, i.e. one derived from the arithmetic mean, one method is where the averaged signal is obtained by processing the direct voltages proportional to the peak acceleration levels at each check point.

If time-division multiplexing (see item 721-04-11 in IEC 50(721)) is used to establish a periodic interrogation of each check point, the interrogation frequency should not be greater than the driving frequency so as to ensure that at least one period of each signal is taken into account. For example, if four transducers are used, at 100 Hz the period of interrogation for each check point should not be less than 0,01 s. There may, however, be problems where such a system is used in conjunction with a tracking filter and due care needs to be taken.

The sampled data system may cause problems when the test is to be controlled to a constant displacement amplitude since the acceleration signal, which is integrated twice, will not be proportional to the displacement amplitude owing to the signal tolerance caused by the phase difference between the sampled signals (see 3.3.2).

It is important that the complete vibration system has a low residual noise level so that most of the tolerance quoted is available during the test (see 4.1.4.1). Typically, 0,6 m/s^2 is an acceptable noise threshold for the vibration system.

A.2.4 *Rotational motion* (see 4.1.2.2)

Large size or high mass specimens can react to the sinusoidal excitation with overturning moments, caused either by the eccentricity of the inertial force of the rigid mass with respect to the thrust axis of the vibration table, or by the distribution of the inertial forces of the modal shapes in correspondence with the natural frequencies. These overturning moments can induce rotational motions around axes lying in any plane orthogonal to the basic motion direction and, as a result, some additional stresses will be caused in the specimen. This could give rise to unrealistically high stresses. Thus it may be appropriate to reduce the rotational motions or at least to know their magnitude. The natural frequencies and relevant modal shapes of the specimen are normally not known before the test and general assumptions regarding these parameters are difficult to make.

Some useful approximate criteria can be obtained by considering the mass of the specimen (m), the mass of the moving parts of the vibration table including fixture (m_t), the distance (d) between the centre of gravity of the specimen and the thrust axis of the vibration table and the height (h) of the centre of gravity of the specimen with respect to the horizontal thrust axis of the vibration table.

For theoretically rigid specimens the maximum foreseen overturning moment (M_o) can be calculated as follows in the presence of a maximum excitation acceleration A:

- rigid mass with eccentricity: $M_o = m \times d \times A$;
- rigid mass with high centre of gravity horizontally excited: $M_o = m \times h \times A$.

For specimens with a resonance in the specified frequency range, the same formulae as above are still valid, but m represents the resonant mass and A is the maximum predicted response acceleration. It is important that, in the above cases, consistent units are used.

Both electrodynamic and servo-hydraulic test equipment have maximum overturning moment limitations. In the case of single vibration generator facilities, of either type, there is a maximum allowable overturning moment, normally specified by the equipment manufacturer in order to avoid vibration generator damage.

In the case of multiple vibration generator facilities there is a maximum ability of the vibration table to counterbalance the overturning moments and to exceed this means to have some rotational motions (pitch or roll) of the vibration table.

The following criteria may be applied.

If the ratio m/m_t is less than 0,2, no check is needed, otherwise the following checks may be appropriate.

For single vibration test equipment (with or without slip tables) and for mechanically guided equipment the overturning moment is counterbalanced by elastic members or bearings. Thus it is only necessary to measure the rotational motion when the specimen overturning moment is greater than 50 % of the maximum allowable overturning moment of the test equipment.

For multiple vibration generators and for test equipment with many degrees of freedom, the overturning moment is counterbalanced by the vibration generators being regulated by a control system. Thus it is only necessary to measure the rotational motion when the specimen overturning moment is greater than the maximum overturning moment capability of the test equipment.

A.3 Testing procedures

A.3.1 *Vibration response investigation* (see 8.1)

Vibration response investigations are of use for many purposes, particularly when it is known that the specimen will experience considerable vibration of a periodic nature such as is found in ships, aircraft, and rotating machinery. The response investigation is also of use when it is considered important to investigate the dynamic behaviour of the specimen and where fatigue is to be assessed.

Due consideration should be given to the amplitude used during the vibration response investigation, particularly with respect to the linearity of the dynamic behaviour of the specimen and also because malfunction and chatter may only occur at the test level.

A vibration response investigation applied before and after the endurance test can be used to identify changes in the frequency at which resonance or some other response occurs. A change in frequency may indicate that some fatigue has occurred and the specimen may, therefore, be unsuitable for the operational environment.

When prescribing the vibration response investigation, the relevant specification should clearly state, where appropriate, the actions to be taken during and following the test, for example:

- any special values of dynamic magnification which, if exceeded, would require endurance by sweeping;
- changes in frequency;
- levels of response which are unacceptable;
- electrical noise.

It is important that any arrangements made to detect the effect upon internal parts during a vibration response investigation should not substantially change the dynamic behaviour of the specimen as a whole. It should also be remembered that, in the case of a non-linear resonance, a specimen may respond differently depending upon the direction of the frequency variation during the sweep. Critical frequencies should be determined on the upward and downward part of the sweep cycle since the specimen may have structurally settled (stabilized) during the upward portion of the sweep.

The starting point of the sweep may be at f_2 instead of f_1, if it is suspected that either a softening or hardening spring non-linearity is present. Critical frequency determination will be different for the upward and downward parts of the sweep.

When digital control is used, it is important that a sufficiently large number of data points are chosen between f_1 and f_2 in order to adequately describe each resonance peak and, therefore, each critical frequency of the specimen. Insufficient data points may result in inaccurate determination of the critical frequencies, especially in the low frequency range with specimens having a low damping ratio. Normally it is considered that sufficient data has been obtained when there are at least three (five if possible) data points within the –3 dB bandwidth of the associated resonance. However, the response investigation will need to be repeated if insufficient data is obtained but there is a strong indication that a resonance exists. In such instances it may also be necessary to sweep over a restricted frequency range.

Further errors in determining the critical frequencies may result from the choice of method for any graphical representation of the data since some systems may be limited in their ability to accurately display all of the data. It may, therefore, be necessary to expand the graph around each critical frequency to overcome this problem.

When a vibration response investigation is called for in the relevant specification the availability of any vibration isolators used is of fundamental importance. If vibration isolators are available, a first investigation is often carried out with the vibration isolators removed or blocked in order to determine the critical frequencies of the specimen.

A second stage may then also be performed in which the vibration response investigation is repeated with the vibration isolators mounted and free so that the effect which they have on the specimen can be determined. At the first stage, different vibration amplitudes will be needed in order to take into account the transmissibility characteristics of the vibration isolators (see figure A.1).

If the isolators are not available, see A.5.1.

A.3.2 *Endurance* (see 8.2)

Endurance by sweeping is normally the most appropriate method for simulating the effect of the stresses undergone by specimens in use (see 8.2.1).

Endurance at fixed frequencies is appropriate to a limited range of service conditions of specimens whose operational site is influenced by machinery or whose installation is restricted to one or a few types of vehicle or aircraft. In these cases, the dominant frequencies are usually known or can be predicted. It may also be appropriate for the rapid accumulation of stress cycles in order to demonstrate the effects of fatigue, for example arising from excitation during a mobile transportation environment (see 8.2.2).

In some cases it may be important to consider possible fatigue aspects at some discrete frequencies, as well as to establish the general ability of a specimen to withstand vibration. Under these circumstances, it would be appropriate to carry out endurance at fixed frequencies followed by endurance by sweeping. This would then provide the information required in the shortest possible time.

In the case of small components, where there is confidence that no resonances exist below 55 Hz or 100 Hz, according to circumstances it is sufficient to commence the endurance at these frequencies.

For endurance testing of an equipment normally mounted on vibration isolators, the vibration isolators are usually fitted. If it is not practicable to carry this out with the appropriate vibration isolators, for example if the equipment is installed together with other equipment on a common mounting device, the equipment may be tested without them at a different severity to be stated in the relevant specification. This amplitude should be determined by taking into account the transmissibility of the vibration isolating system in each axis used for the test. When the characteristics of the vibration isolators are not known, refer to A.5.1.

The relevant specification may require an additional test on a specimen with the external vibration isolators removed or blocked in order to demonstrate that minimum acceptable structural resistance has been achieved. In this case, the severity to be applied should be given in the relevant specification.

A.4 **Test severities** (see clause 5)

A.4.1 *Selection of test severities*

The frequencies and amplitudes given have been selected to envelop the frequency responses appropriate to a wide range of applications. When an equipment is for use in one application only, it is preferable to base the severity on the vibration characteristics of the actual environment, if known. When the vibration conditions of the actual environment are not known for an equipment, the appropriate test severity should be selected from annex C which gives examples of test severities related to various applications.

In determining the test severity, the specification writer should take into account the information given in IEC 721 (see clause 5).

As the value of displacement amplitude is associated with a corresponding value of acceleration amplitude in such a manner that the magnitude of vibration is the same at the cross-over frequency, the frequency range may be swept continuously, changing from constant displacement to constant acceleration and vice versa at the cross-over frequency. Cross-over frequencies between 8 Hz and 10 Hz and between 58 Hz and 62 Hz are given.

Cross-over frequencies other than the standard ones may be required where it is desirable to simulate the actual environment, if known. If this results in a high cross-over frequency the capability of the vibration generator must be borne in mind. It is important that the displacement amplitude chosen does not correspond to an acceleration amplitude in the low frequency region comparable to the residual noise level of the vibration system. If necessary, the problem could be overcome by either using a tracking filter or, if the test was conducted all at low frequencies, to employ a displacement transducer in the control loop (see 5.2).

A.4.2 *Selection of test severities for components*

The selection of test severities for components is complicated by the fact that, in many cases, it is not known in which equipment they are to be installed nor the stresses to which they will be subjected. Even where it is known that components are for use in specific items of equipment, it should be borne in mind that the vibration environment to which the component will be subjected may be different from that to which the equipment will be subjected, due to the dynamic response of the structure, equipment, sub-assemblies, etc. Caution should, therefore, be observed in selecting component test severities related to equipment severities and some margin may need to be allowed for the effect of these responses.

Where components are mounted in the equipment in a manner designed to protect them from vibration, the equipment test severities, or possibly a lower severity, may be appropriate.

An alternative approach to the selection of component test severities is to test and grade components to stated severities so that equipment designers may select components appropriate to their application.

Reference should be made to annex B which gives examples of severities related to various applications.

A.4.3 *Sweep*

During sweeping, the frequency is required to change exponentially with time so that:

$$\frac{f}{f_1} = e^{kt}$$

where

- f is the frequency;
- f_1 is the lower frequency limit of the sweep;
- k is a factor depending on sweep rate;
- t is the time.

For this test, the sweep rate is one octave per minute (see 4.1.6) and thus $k = \log_e 2 = 0{,}693$, if the time is expressed in minutes.

The number of octaves for a sweep cycle is given by:

$$X = 2 \log_2 \left(\frac{f_2}{f_1} \right) = \frac{2}{\log_{10} 2} \log_{10} \left(\frac{f_2}{f_1} \right) = 6{,}644 \log_{10} \left(\frac{f_2}{f_1} \right)$$

where

X is the number of octaves;

f_1 is the lower frequency limit of the sweep;

f_2 is the upper frequency limit of the sweep.

Values produced utilizing the above formula are given in table A.1 and show the rounded times associated with the recommended numbers of sweep cycles and frequency ranges (see 5.3.1).

For a digital system the output sine wave can be produced either from an external analogue synthesizer or internally from a frame of digital data containing a portion of a sinusoidal signal.

In the first case, a pure continuous sine wave is generated; this results in there being no difference between analogue and digital systems.

In the second case, the analogue drive frame produced by the D/A converter is not smooth, but consists of a number of small steps. A smoothing filter is necessary to operate on the signal to smooth out these steps and produce an essentially pure sinusoidal shape. It is also important to ensure that the drive frames are joined so as to produce a smooth sine wave.

Table A.1 – Number of sweep cycles and associated endurance times per axis

Frequency range Hz	Number of sweep cycles						
	1	2	5	10	20	50	100
1 to 35	10 min	21 min	50 min	1 h 45 min	3 h 30 min	9 h	17 h
1 to 100	13 min	27 min	1 h 05 min	2 h 15 min	4 h 30 min	11 h	22 h
10 to 55	5 min	10 min	25 min	45 min	1 h 45 min	4 h	8 h
10 to 150	8 min	16 min	40 min	1 h 15 min	2 h 30 min	7 h	13 h
10 to 500	11 min	23 min	55 min	2 h	3 h 45 min	9 h	19 h
10 to 2 000	15 min	31 min	1 h 15 min	2 h 30 min	5 h	13 h	25 h
10 to 5 000	18 min	36 min	1 h 30 min	3 h	6 h	15 h	30 h
55 to 500	6 min	13 min	30 min	1 h	2 h	5 h	11 h
55 to 2 000	10 min	21 min	50 min	1 h 45 min	3 h 30 min	9 h	17 h
55 to 5 000	13 min	26 min	1 h 05 min	2 h 15 min	4 h 15 min	11 h	22 h
100 to 2 000	9 min	17 min	45 min	1 h 30 min	3 h	7 h	14 h

NOTES

1 The endurance times given in the table have been calculated for a sweep rate of one octave per minute and are rounded up or down. The error caused by this in no case exceeds 10 %.

2 The figures underlined have been derived from annexes B and C.

An estimation of the number of stress cycles (N), the number of octaves (X) and the sweep duration (T) for one sweep cycle ($f_1 \rightarrow f_2 \rightarrow f_1$) may be obtained from the following:

$$N = \frac{(f_2 - f_1) \times 60 \times 2}{\log_e 2 \times SR} \quad \text{(stress cycles)}$$

$$X = \frac{\log_e \left(\frac{f_2}{f_1}\right) \times 2}{\log_e 2} \quad \text{(octaves)}$$

$$T = \frac{X}{SR} = \frac{\log_e \left(\frac{f_2}{f_1}\right) \times 2}{\log_e 2 \times SR} \quad \text{(minutes)}$$

where

f_2 is the upper frequency limit of the sweep;

f_1 is the lower frequency limit of the sweep;

SR is the sweep rate in octaves/minute.

This method of estimation of the number of stress cycles is also valid for tables B.1, C.1 and C.2.

A.4.4 *Tracking filters*

A.4.4.1 *Analogue filters*

These may be constant bandwidth (CB) or constant percentage bandwidth (CPB). In each case the response time (T_r) is given by:

$$T_r = \frac{1}{BW}$$

where

T_r is in seconds;

BW is the bandwidth in hertz (Hz).

For example:

for a CB type of filter set to 10 Hz bandwidth

$T_r = \frac{1}{10}$ = 100 ms and is constant across the whole tuning range;

for a CPB type of filter set, for example, to 10 % at the tuned frequency f

$BW = 0{,}1\ f$;

$T_r = \frac{1}{BW}$ = 10 periods at the tuned frequency.

When tracking filters are used in a control loop the response time is very important. A long response time can slow down the overall control response and may result in instability or even loss of control. In addition, the response time may limit the sweep speed in swept sine tests, particularly at low frequencies for CPB types where T_r can be tens of seconds (see 4.1.3).

For this reason many tracking filters compromise by having either multiple CB settings, automatically switched by the tuning frequency, or they have a CB response at low frequencies up to some set frequency and CPB response above this.

As a general rule, the tracking filter should respond at least five times faster than the controller compression speed in order to prevent mutual interaction and control instability. The filter bandwidth will need always to be less than the working tuned frequency.

See tables A.2 and A.3 for response times.

Table A.2 – CB response time

Bandwidth Hz	Time s
0,1	10
0,5	2
1	1
5	0,2
10	0,1

Table A.3 – CPB response time

Frequency Hz	Bandwidth %		
	1	5	10
	Time s	Time s	Time s
5	20	4	2
10	10	2	1
50	2	0,4	0,2
100	1	0,2	0,1
500	0,2	0,04	0,02
1 000	0,1	0,02	0,01
2 000	0,05	0,01	0,005

A.4.4.2 *Digital filters*

Digital systems employ a numerical algorithm technique to reproduce an equivalent of an analogue tracking filter. The final result is no different in the extraction of the fundamental signal but, in the case of digital control, it could be at the cost of increasing the loop response time. This may effect the accuracy of the control at higher frequencies.

A.4.5 *Control signal measurement*

Digital systems employ an anti-aliasing filter before digitizing the data. This filter is progressively stepped along the frequency range as the frequency sweep progresses and has the effect of removing the high frequency components. As a result of this, the signal seen by a digital system may have a lower r.m.s. value, which could result in the digital system controlling the test at a higher level when compared to an equivalent analogue control system. Use of a tracking filter with both digital and analogue control systems will overcome this problem.

A.5 Equipment normally used with vibration isolators

A.5.1 *Transmissibility factors for vibration isolators*

When a specimen would normally be mounted on vibration isolators, but they are not available and their characteristics are unknown and, in addition, the relevant specification has not allowed for this situation, it is necessary to modify the specified level in such a way as to provide a more realistic vibration input to the specimen. It is recommended that this modified level be derived by using values taken from the curves given in figure A.1 described below:

a) curve A relates to a type of loaded vibration isolator of high resilience having a natural frequency, when considering a single degree of freedom, not exceeding 10 Hz;

b) curve B relates to a type of loaded vibration isolator of medium resilience having a natural frequency, as qualified above, in the range 10 Hz to 20 Hz;

c) curve C relates to a type of loaded vibration isolator of low resilience having a natural frequency, as qualified above, in the range of 20 Hz to 35 Hz.

Curve B is derived from vibration measurements made on typical aircraft equipment fitted with highly damped all-metal mountings having a natural frequency of approximately 15 Hz considering a single degree of freedom.

Very little data were available for vibration isolators represented by curves A and C. These were derived by extrapolation from curve B, considering natural frequencies of 8 Hz and 25 Hz respectively.

The transmissibility curves have been estimated to envelop the transmissibility characteristics likely to arise in an installation in which modes are coupled. The use of these curves, therefore, makes an allowance for the vibration levels arising at the periphery of a specimen from the combined effects of translational and rotational motions.

The most appropriate transmissibility curve should be selected from figure A.1 and the specified vibration levels should be multiplied by values taken from this curve over the required frequency range. The product of these values may result in test levels which may not be reproducible in the laboratory. In this case the test engineer should adjust the levels in such a way that the maximum possible level is achieved at all times throughout the complete frequency range. It is of the utmost importance that the actual values used are stated in the test report.

A.5.2 *Temperature effect*

It is important to note that many vibration isolators contain material which is temperature-dependent. If the fundamental resonance frequency of the specimen on the vibration isolators is within the test frequency range, caution must be exercised in deciding the length of time for which any endurance should be applied. In some circumstances it may be unreasonable to apply continuous excitation without permitting recovery. If the actual time distribution of excitation of this fundamental resonance frequency is known, an attempt should be made to simulate it. If the actual time distribution is not known then excessive overheating should be avoided by limiting the periods of excitation in a manner which will require engineering judgement, taking into account 5.3.

A.6 Duration

A.6.1 *Basic concept* (see 5.3.1)

Many existing specifications describe the sweep endurance phase of a vibration test in terms of time duration. This makes it virtually impossible to correlate the behaviour of one resonant specimen with another if their frequency ranges are dissimilar, since the number of occasions on which the resonance will be excited will be different. For instance, it is often considered that, for a given acceleration value and endurance time, the test is more severe with a wide frequency range than with a narrow one; in fact the reverse is the case. The concept of the number of sweep cycles as an endurance parameter overcomes this problem since the resonances will be excited equally, irrespective of the frequency range.

A.6.2 *Test*

Where the test is simply to demonstrate the ability of a specimen to survive and/or operate at the appropriate amplitudes, the test need only continue for a duration sufficient to demonstrate this requirement over the specified frequency range. In cases where the ability of an item to withstand the cumulative effects of vibration such as fatigue and mechanical deformation is to be demonstrated, the test should be of a sufficient duration to accumulate the necessary stress cycles. For demonstration of unlimited fatigue life, a total of 10^7 stress cycles is normally considered adequate.

A.7 Dynamic response

The major causes of damage are the dynamic stresses produced within the test specimen. The classic example is the stress produced within a simple spring/mass system when the system is attached to a vibrating body whose inertia is large in relation to that of the mass. At the frequency of resonance the spring/mass responds with an increase in amplitude of motion, inducing increased stress in the spring. The performance of an endurance test at such a resonance frequency requires a great deal of engineering judgement. The difficulty lies mainly in determining which resonances are significant. An additional problem might be that of maintaining the driving frequency at resonance.

At higher frequencies particularly, the resonances may not be very apparent but nevertheless high stress levels may occur locally. Whilst some specifications attempt to define the severity of a resonance by an arbitrary value for the dynamic magnification, this method has not been adopted for this test.

The procedures given herein imply that the vibration amplitude (displacement or acceleration) shall be kept to a prescribed value independent of the dynamic reaction of the specimen. This is in accordance with the state of the art of vibration testing of a general kind suitable for standardization.

It is well known that when a specimen is excited at its resonance frequency, its apparent mass can be high in relation to that of its operational mounting structure. In such a case the reaction of the specimen can be considerable. The driving force and the mechanical impedance of the structure are normally not known and general assumptions regarding these parameters are usually extremely difficult to make.

Force control is foreseen as a means of reducing the above problem but is not included in the test, since it is not possible at present to give information on procedures, measurements and tolerances. When such a test is called for by the relevant specification, it is possible either to use force transducers or to rely on a measurement of the driving current. This latter procedure has certain drawbacks, since the current may not be proportional to the force over parts of the frequency range specified for the test. Nevertheless, with good engineering judgement the method utilizing current measurement can be used, particularly if a limited frequency range is involved.

Thus, whilst a force-controlled test may appear to be attractive, caution must be exercised in its use. Certainly in some cases, for example components, the amplitude-controlled test is almost always more appropriate (see clause 8).

A.8 Performance evaluation

When appropriate, items should be operated either throughout the test or at appropriate phases of the test, in a manner representative of their functioning conditions. At suitable intervals throughout the endurance phase, and towards the end of it, functional checks of the specimen are recommended.

For specimens in which vibration may influence the switch-on and switch-off function (e.g. interfering with the operation of a relay) such functioning should be repeated to demonstrate a satisfactory performance in this respect, either over the frequency range of the test, or at those frequencies likely to cause interference.

If the test is to demonstrate survival only, the functional performance of specimens should be assessed after the completion of vibration endurance (see 8.2 and clause 11).

A.9 Initial and final measurements

The purpose of the initial and final measurements is to compare particular parameters in order to assess the effect of vibration on the specimen.

The measurements may include, as well as visual requirements, electrical and mechanical operational and structural characteristics (see clauses 7 and 11).

Annex B
(informative)

Examples of severities primarily intended for components

The possible number of severities allowed by clause 5 is very large. To simplify the application of this standard, examples of severities primarily intended for components have been selected from the recommended parameters for endurance stated in clause 5 of this test and are given in table B.1. The conditions for testing are as prescribed in this standard.

Table B.1 – Endurance by sweeping – Examples with higher cross-over frequency

	Number of sweep cycles in each axis			Examples of application
Frequency range Hz \ Amplitude [1)]	0,35 mm or 50 m/s^2	0,75 mm or 100 m/s^2	1,5 mm or 200 m/s^2	
10 to 55	10	10		Large industrial power plant, heavy rotating machinery, steel rolling mills, large merchant and naval ships
10 to 500	10	10		General purpose land-based and land transport, fast small marine craft (naval or civil) and general aircraft use
10 to 2 000		10	10	Space launchers (200 m/s^2). Engine mounted components in aircraft
55 to 500	10	10		Application as for 10 Hz to 500 Hz but applicable to small rigid components with no resonance response at frequencies below 55 Hz
55 to 2 000		10	10	Application as for 10 Hz to 2 000 Hz but applicable to small rigid components with no resonance response at frequencies below 55 Hz
100 to 2 000		10	10	Application as for 55 Hz to 2 000 Hz but applicable to very small components of very rigid construction, for example, encapsulated transistors, diodes, resistors, capacitors and integrated circuits

NOTE – Where there is more than one amplitude for a stated frequency range, only one is used.

1) Displacement amplitude below the cross-over frequency and acceleration amplitude above the cross-over frequency. The cross-over frequencies are between 58 Hz and 62 Hz (see 5.2 and table 5).

For a method of estimation of the number of stress cycles see A.4.3.

Endurance at fixed frequencies

The typical durations for the endurance at each critical frequency in each axis are 10 min, 30 min, 90 min and 10 h.

For almost fixed frequencies see A.1.

For predetermined frequencies an endurance time should be chosen so that an upper limit of 10^7 stress cycles is applied for each stated combination of frequency and axis. When the environmental conditions are well known the time duration to be applied at fixed frequencies should be based upon the number of stress cycles that occur during a normal lifetime.

Annex C
(informative)

Examples of severities primarily intended for equipment

When the actual vibration severity is known, it should be used (see A.4.1). When the severity is not known, it is necessary to make an arbitrary choice, but one which is based, as far as possible, on similar generalized severities for related applications as given in this annex.

Several combinations of frequency range, vibration amplitude and endurance duration are given as examples of severities primarily intended for the testing of equipment, and other articles (see tables C.1 and C.2). These severities have been selected from the recommended parameters for endurance stated in clause 5 of this standard and they are considered to cover the more common applications of the vibration test. No attempt has been made to produce an exhaustive list and requirements not covered by this annex should be chosen from the other recommended severities of this standard and should be prescribed in the relevant specification.

In certain applications, it may not be practicable to use endurance by sweeping and it may be necessary to carry out tests at critical frequencies. Such tests should be prescribed by the relevant specification, in accordance with the appropriate clauses of this standard, and using this annex for guidance.

Table C.1 – Endurance by sweeping – Examples with lower cross-over frequency

	Number of sweep cycles in each axis			Examples of application
Acceleration m/s² / Frequency range Hz	5	10	20	
10 to 150	50	–	–	Stationary equipment such as large computers and rolling mills, long-term exposure
10 to 150	20	–	–	Stationary equipment such as large transmitters and air conditioners, intermittent exposure
10 to 150	–	20	20	Equipment intended for installation in or transport by ships, railway and land vehicles

NOTE – Where there is more than one amplitude for a stated frequency range, only one is used.

For a method of estimation of the number of stress cycles, see A.4.3.

Endurance at fixed frequencies

The typical durations for the endurance at each critical frequency in each axis are 10 min, 30 min, 90 min and 10 h.

For almost fixed frequencies see A.1.

For predetermined frequencies an endurance time should be chosen so that an upper limit of 10^7 stress cycles is applied for each stated combination of frequency and axis. When the environmental conditions are well known the time duration to be applied at fixed frequencies should be based upon the number of stress cycles that occur during a normal lifetime.

Table C.2 – Endurance by sweeping – Examples with higher cross-over frequency

	Number of sweep cycles in each axis				Examples of application
Amplitude [1)] / Frequency range Hz	0,15 mm or 20 m/s²	0,35 mm or 50 m/s²	0,75 mm or 100 m/s²	1,5 mm or 200 m/s²	
1 to 35[2)]	–	100	100	–	Equipment mounted adjacent to heavy rotating machinery
10 to 55[2)]	10 20 100	– 20 –	– – –	– – –	Equipment intended for large power plants and for general industrial use
10 to 150	10 20 100	– 20 –	– – –	– – –	Equipment intended for large power plants and for general industrial use, where it has been found that appreciable vibration components exist beyond 55 Hz
10 to 500	10	10	–	–	Equipment for general aircraft use, the higher values apply to equipment close to, but not within, the engine compartment
10 to 2 000	–	10	10	–	Equipment for high-speed aircraft, the higher values apply to equipment close to, but not within, the engine compartment
				10	Aircraft engine compartments

NOTE – Where there is more than one amplitude for a stated frequency range, only one is to be used.

[1)] Displacement amplitude below the cross-over frequency and acceleration amplitude above the cross-over frequency 58 Hz to 62 Hz (see 5.2 and table 5).

[2)] Constant displacement amplitude test.

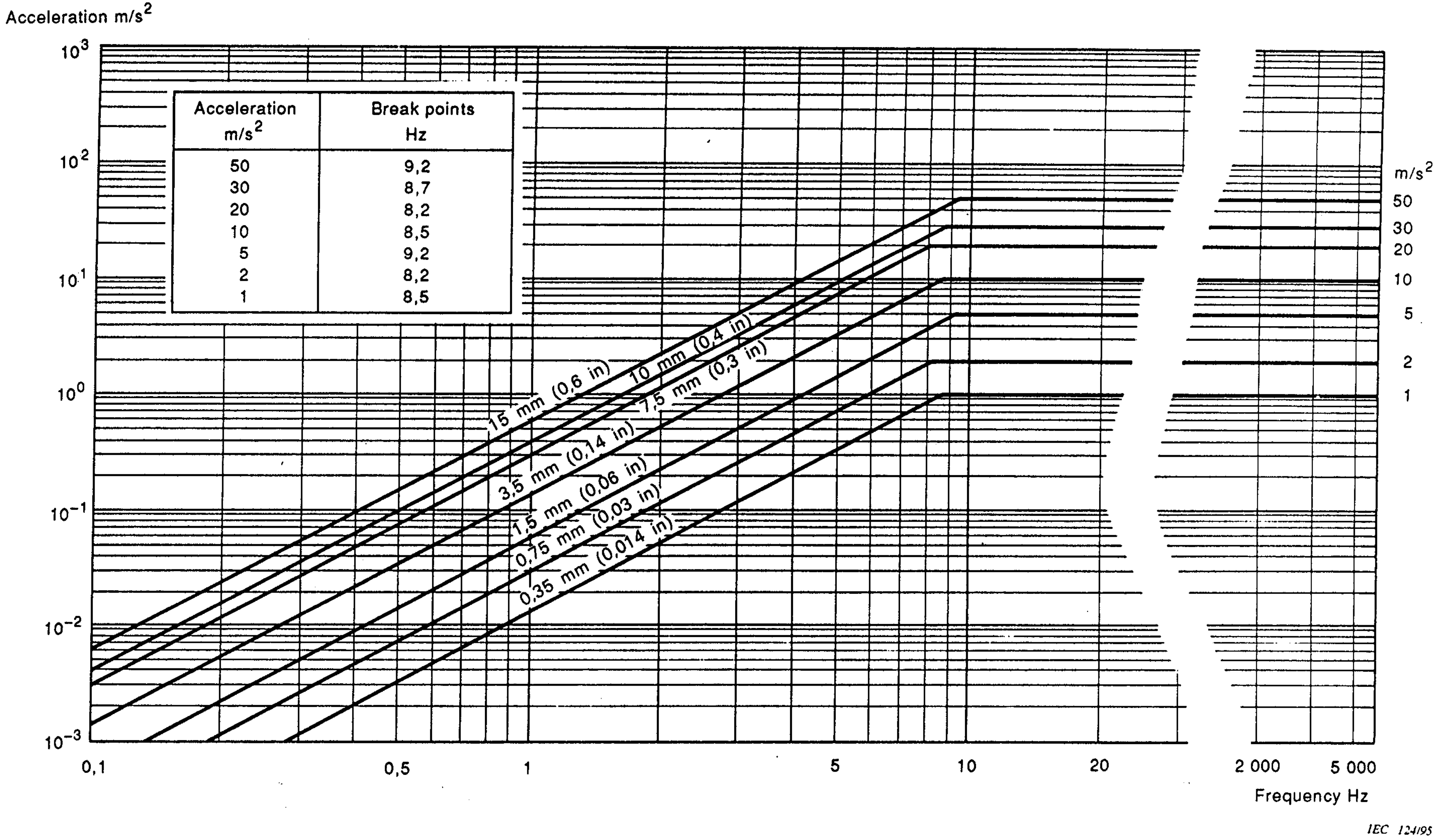
For a method of estimation of the number of stress cycles see A.4.3.

Endurance at fixed frequencies

The typical durations for the endurance at each critical frequency in each axis are 10 min, 30 min, 90 min and 10 h.

For almost fixed frequencies see A.1.

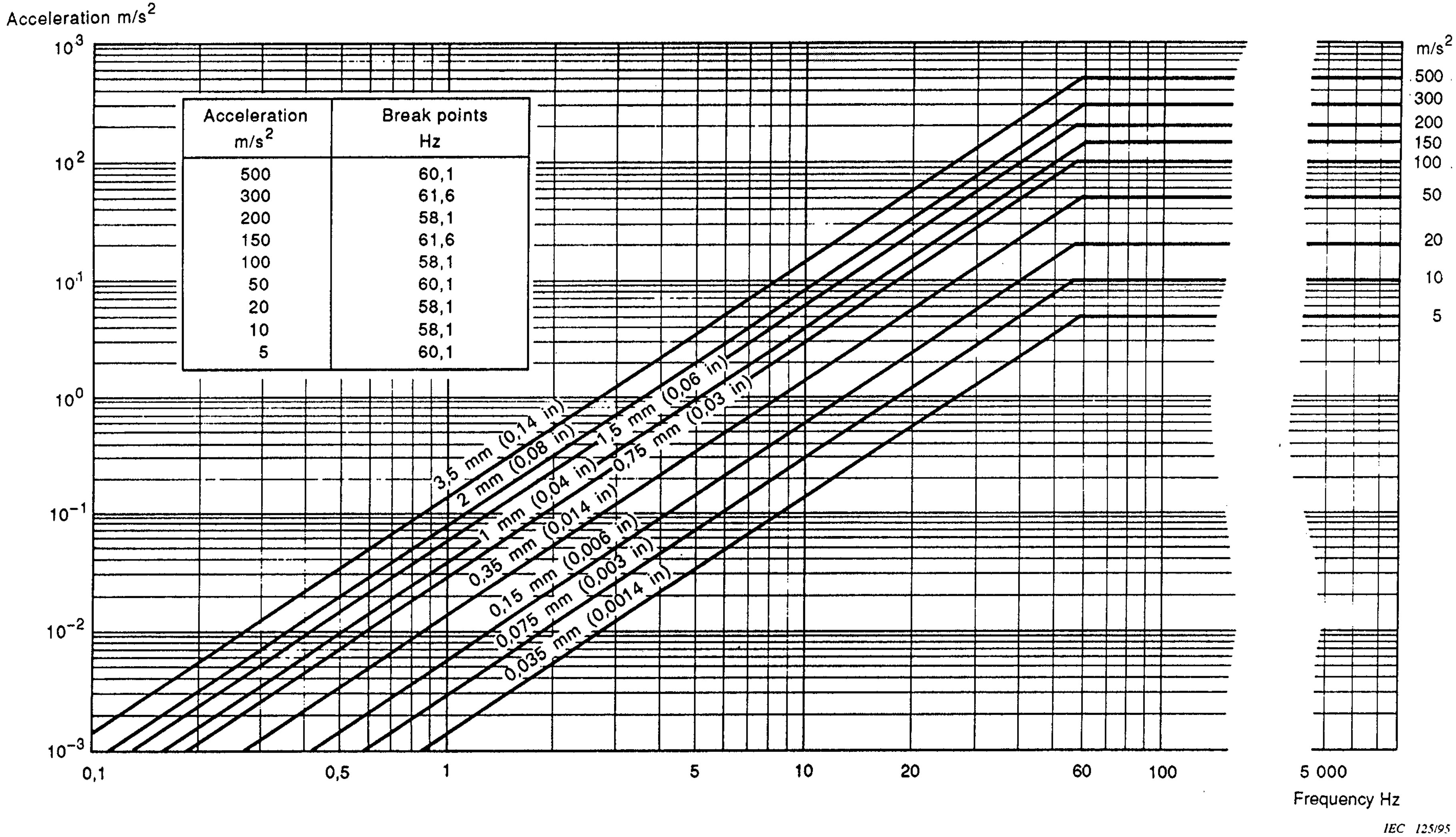
For predetermined frequencies an endurance time should be chosen so that an upper limit of 10^7 stress cycles is applied for each stated combination of frequency and axis. When the environmental conditions are well known the time duration to be applied at fixed frequencies should be based upon the number of stress cycles that occur during a normal lifetime.



Acceleration m/s²	Break points Hz
50	9,2
30	8,7
20	8,2
10	8,5
5	9,2
2	8,2
1	8,5

NOTE – This nomogram should not be taken as being a precise graphical representation of the severities.

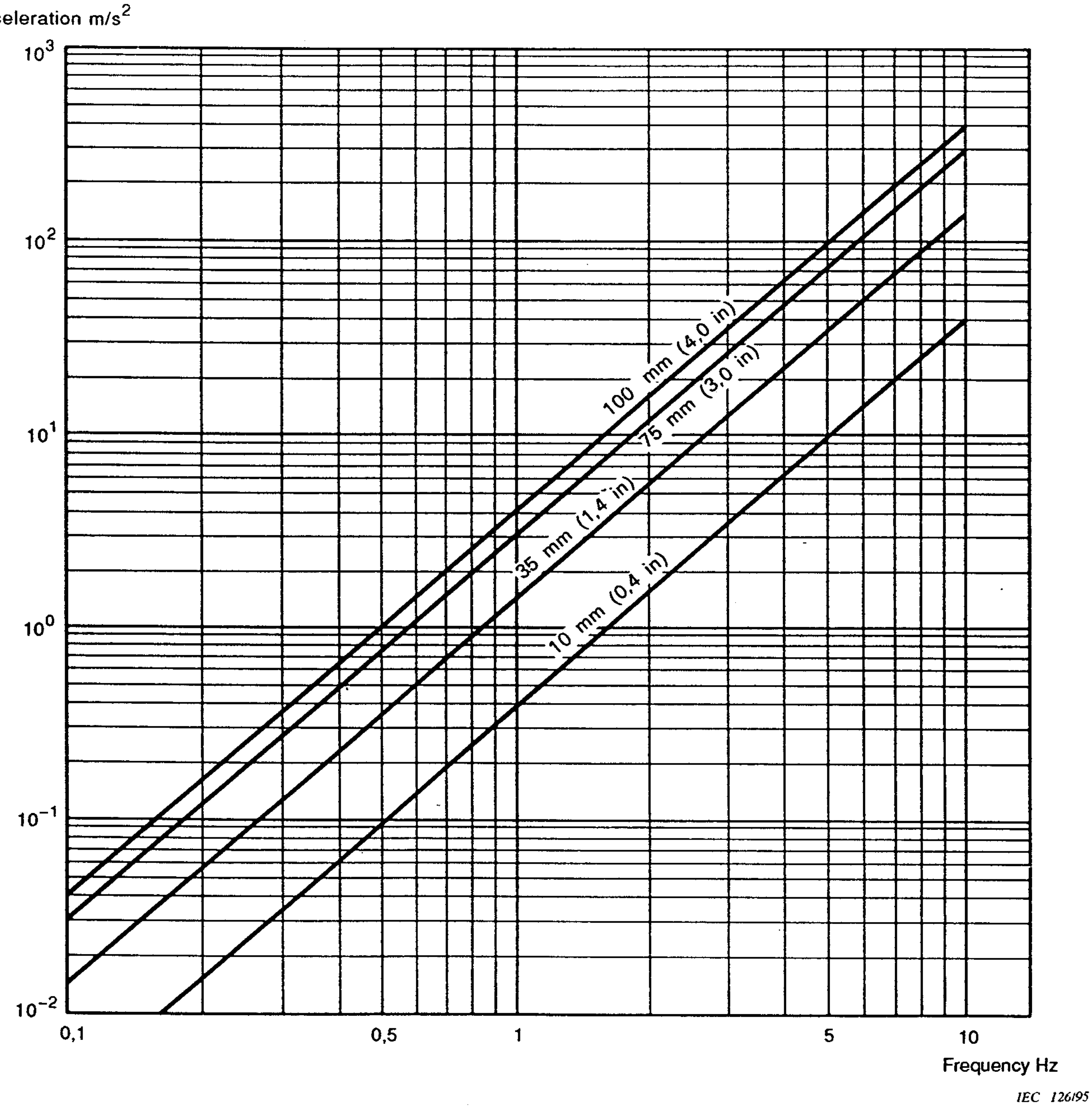
Figure 1 – Nomogram relating vibration amplitude to frequency with lower cross-over frequency (8 Hz to 10 Hz)



Acceleration m/s²	Break points Hz
500	60,1
300	61,6
200	58,1
150	61,6
100	58,1
50	60,1
20	58,1
10	58,1
5	60,1

NOTE – This nomogram should not be taken as being a precise graphical representation of the severities.

Figure 2 – Nomogram relating vibration amplitude to frequency with higher cross-over frequency (58 Hz to 62 Hz)



NOTE – This nomogram should not be taken as being a precise graphical representation of the severities.

Figure 3 – Nomogram relating vibration displacement amplitude to frequency (only applicable for frequency ranges with an upper frequency of 10 Hz)

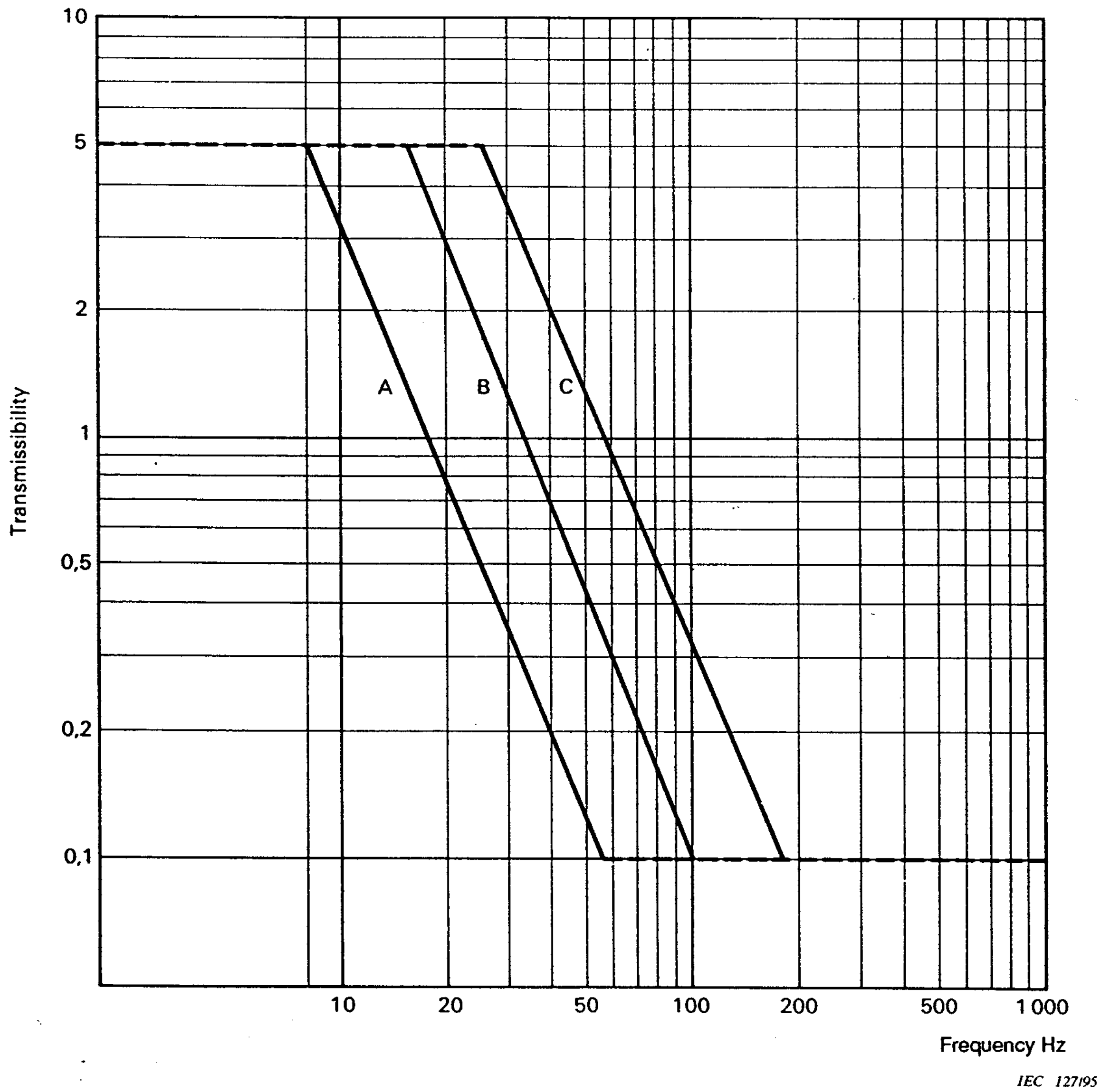


Figure A.1 – Generalized transmissibility factors for vibration isolators

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